SPARNET – Spartan Data Network for Real-Time Physiological Status Monitoring

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U.S. Army Telemedicine Partnership Series 2008: "Personal Health Monitoring"

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Outline

1. Overview of USARIEM
2. Need for real-time physiological monitoring
   - Ranger Training
   - CST-WMD
3. Overview of Spartan data networks (SPARNET)
   - Inductive-Personal Area Network
   - Software-defined Squad Area Network
4. Conclusions

U.S. Army Research Institute Environmental Medicine (USARIEM)

- A subordinate laboratory of the U.S. Army Medical Research and Materiel Command
- Mission: conduct basic and applied research to determine how extreme heat, severe cold, high terrestrial altitude, occupational tasks, physical training, deployment operations, and nutritional factors affect the health and performance of military personnel

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Physiological Monitoring and Predictive Modeling

Develop wearable physiological sensor systems that collect, organize and interpret data on Soldier health status

Develop thermoregulatory models and decision aids to predict risk and performance decrements for Soldiers under the stresses of heat, cold and high altitude

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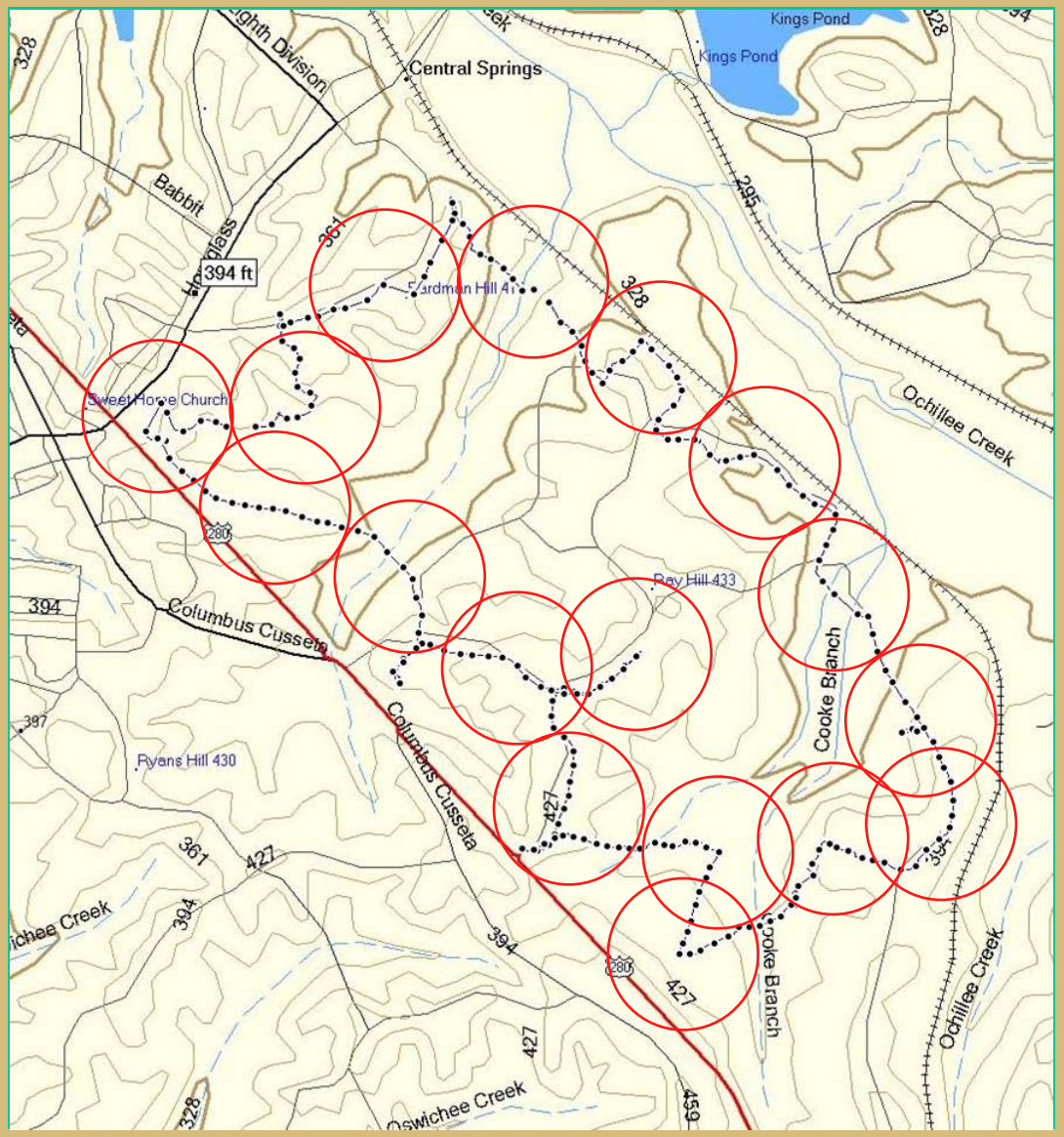
Real-time physiological monitoring applications

Ranger Training Brigade, Fort Benning, GA

Mitigate risk of injury and separation by tracking Ranger student physiological status and physical location during higher risk training activities.

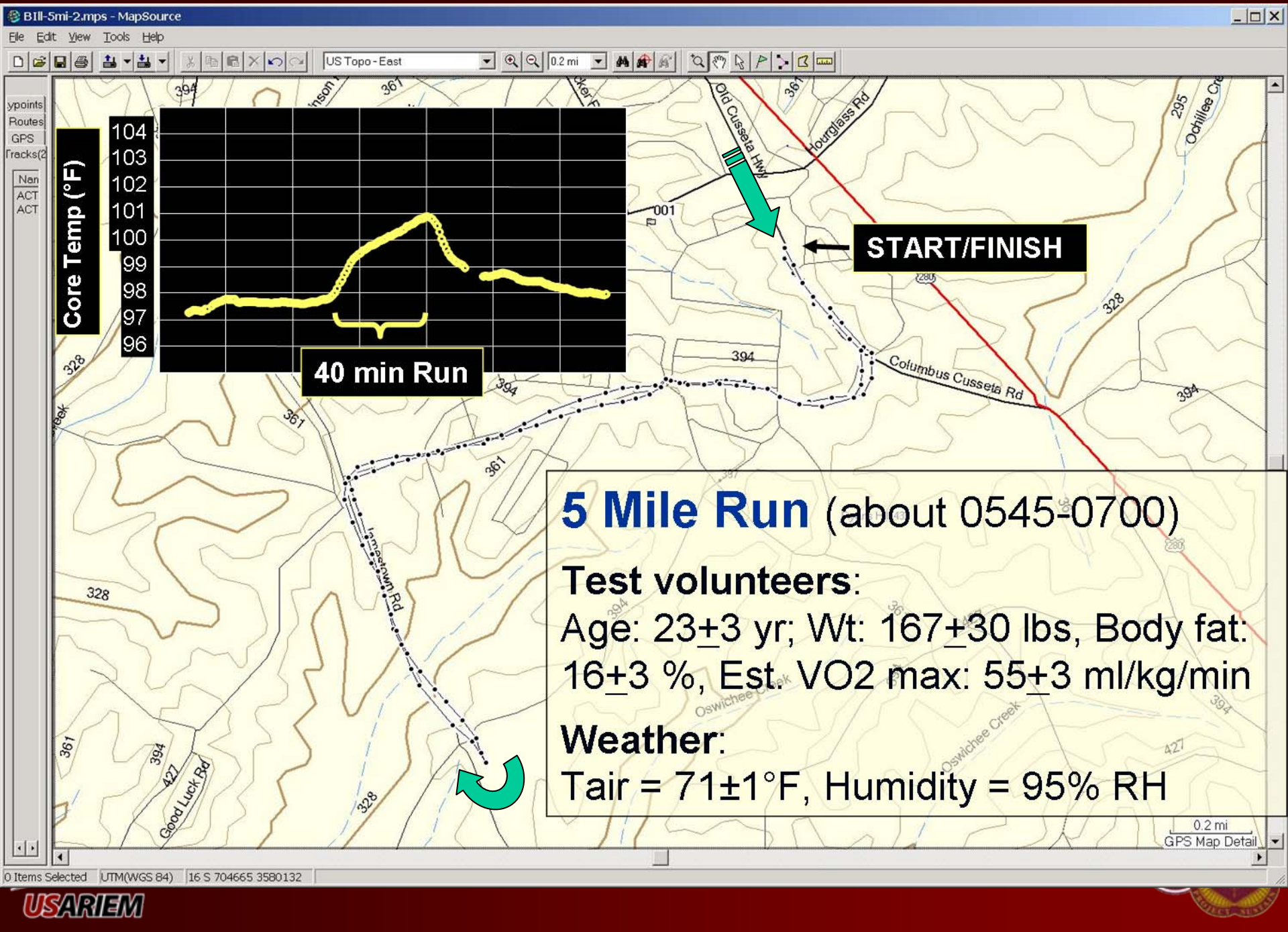
Land Navigation Training Area



RANGER
AIRBORNE
FOLLOW ME

USARIEM

5 Mile Run - 8 min / mile

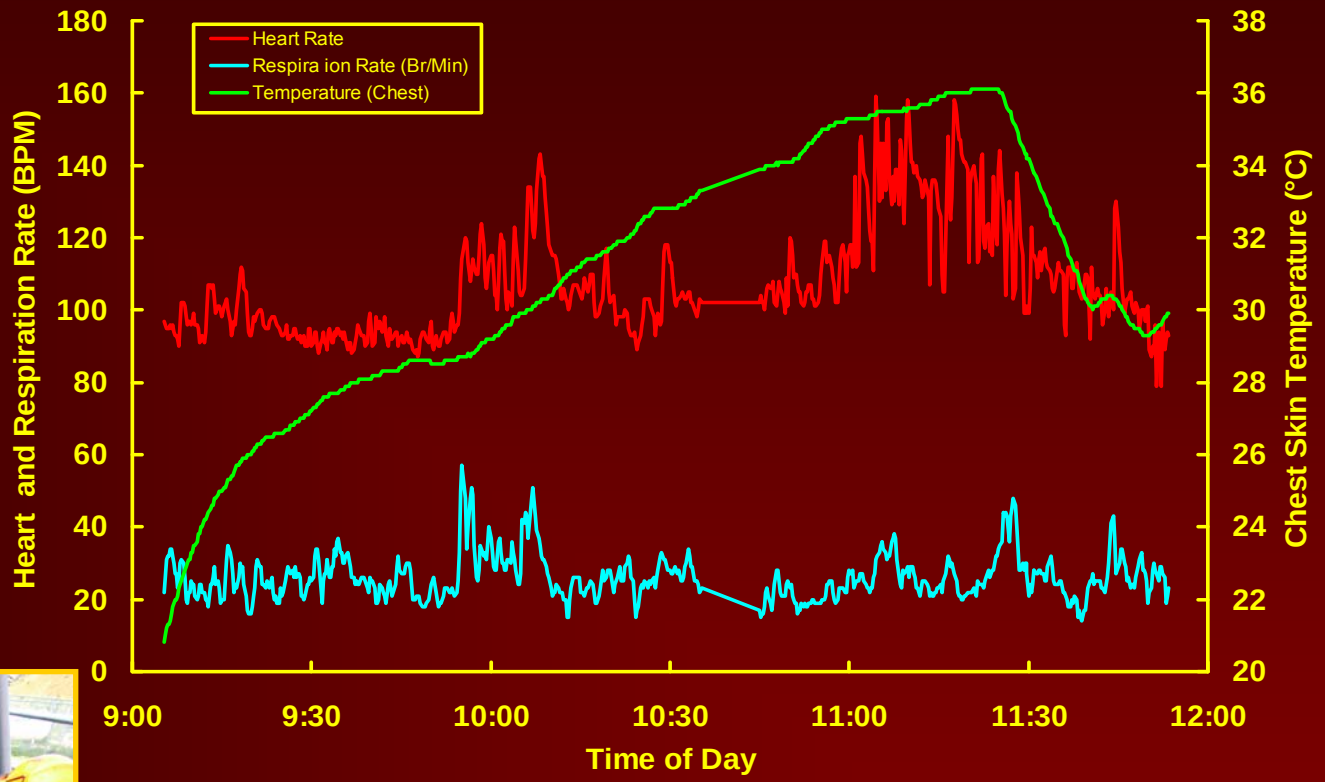

Bill-5mi-2.mps - MapSource
File Edit View Tools Help
US Topo - East
0.2 mi
Core Temp (°F)
104
103
102
101
100
99
98
97
96
40 min Run
START/FINISH
Old Cusseta Hwy
Hourglass Rd
Columbus Cusseta Rd
Jamestown Rd
Good Luck Rd
Oswichee Creek
5 Mile Run (about 0545-0700)
Test volunteers:
Age: 23±3 yr; Wt: 167±30 lbs, Body fat: 16±3 %, Est. VO2 max: 55±3 ml/kg/min
Weather:
Tair = 71±1°F, Humidity = 95% RH
0.2 mi
GPS Map Detail
0 Items Selected
UTM(WGS 84)
16 S 704665 3580132

Civil Support Team–Weapons of Mass Destruction (CST-WMD)

MEDICAL MONITORING TELEMETRY SYSTEM

Proactive medical monitoring can decrease serious injuries and loss of operational strength/readiness by tracking changes and trends in vital signs/core temperatures and taking action before they become symptomatic and result in a medical emergency "man-down" scenario

Medical Monitoring Telemetry

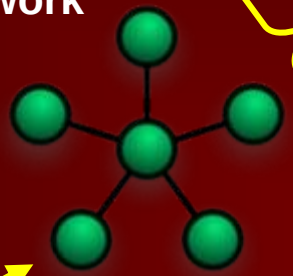


Spartan data networks (SPARNET)

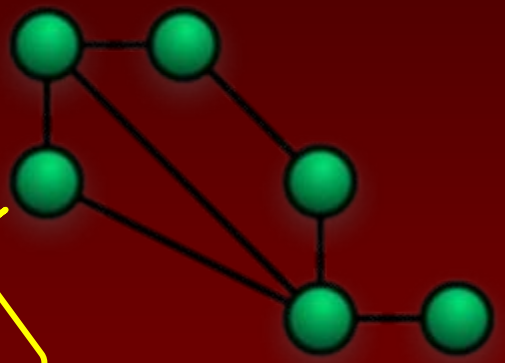
Squad Area Data Network

Inductive - Personal Area Network

Physio-sensor node



Star



Mesh

SPARNET Goal

Develop a state-of-the-art wireless squad and personal area network that enable existing physio-sensors, algorithms, and interfaces to form real-time medical and situational awareness products for foot Soldiers

- Use network monitoring of physiology and geolocation to:
  - Minimize casualties and improve casualty management
  - Improve mission planning and risk management
  - Increase mission training opportunities

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SPARNET Guiding Principles

- Minimalism
  - Focus requirements to minimize risk/cost
- Flexibility and adaptability technologies
  - Open, easily-modified, “white box”
  - Facilitates response to specialized needs
- Focus on dismounted soldier needs
  - Establish close partnerships

Multidisciplinary "triple helix" Community Infrastructure Project

Government (Army)

- **Military customers, program leadership, science and engineering expertise** (textile prototypes, physiological monitoring and biomedical modeling, data base)
- **Regulatory and safety oversight** (RF safety, Army Spectrum Manager, IRB)
- **Funding**: SBIR/STTR, TATRC, MRMC

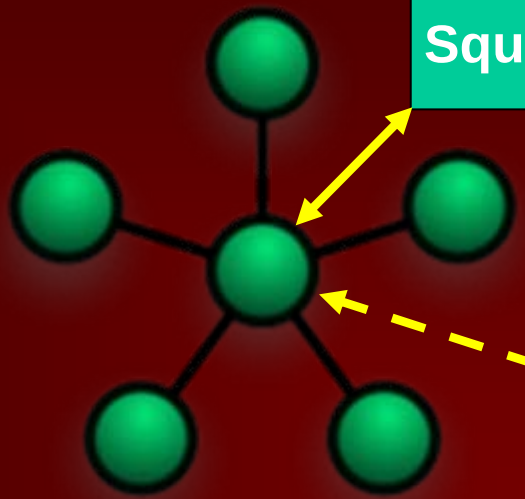
Small business

- **Engineering leadership and expertise**: Elintrix.com
  - Software defined radios (RF and inductive networks)
  - Situational Awareness application

Academia

- **Wearable antenna design**: Ohio State Univ. ElectroScience Laboratory
- **Power efficient radio and network operation**: Univ. of California San Diego
- **Metabolic rate algorithms**: Rice University

Personal Area Sensor Network



Squad area network

Sensor node

Artifact management

On-the-fly data analysis

Hub

Data synthesis

Provide information to Squad Area Network

VitalSense® Integrated Physiological Monitoring System (MiniMitter.com)

- Ingestible temperature pill
- Skin temperature patch
- Push PAN (unidirectional)
- Near field RF
- Resistant to interference
- Data logger
- FDA 510k

Warfighter Physiological Status Monitoring (WPSM)

Vital Sign Detection System (Hidalgo, Ltd, UK)

Sensor node: ECG, respiration, actigraphy, body orientation, skin temp

←Core Temp (MiniMitter) Ingestible Thermometer Pill

← Fluid Intake Monitor

←Sleep Watch

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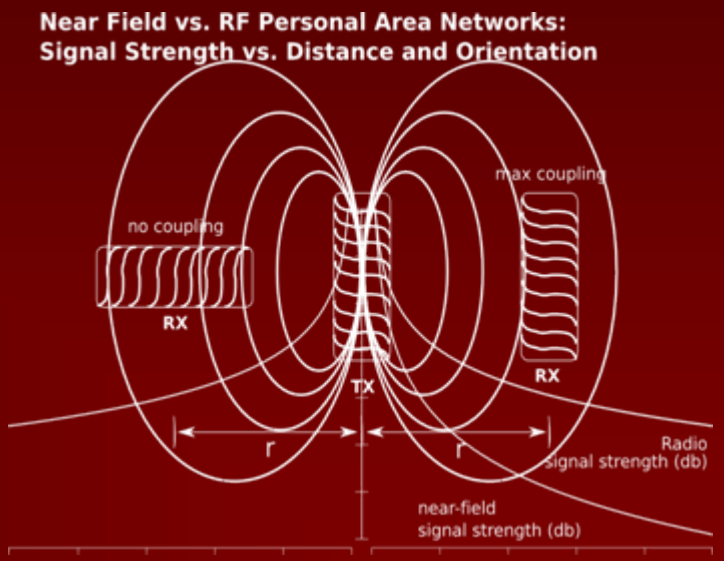
Future → Inductive-PAN

- Free space magnetic induction
  - Inherently short range/near-field
    - Body Bubble
    - Spatial reuse of spectrum
  - Tissue transparent
  - Issue: No adequate COTS transceiver available
  - BioNet – ground-up nodes being developed (STTR)



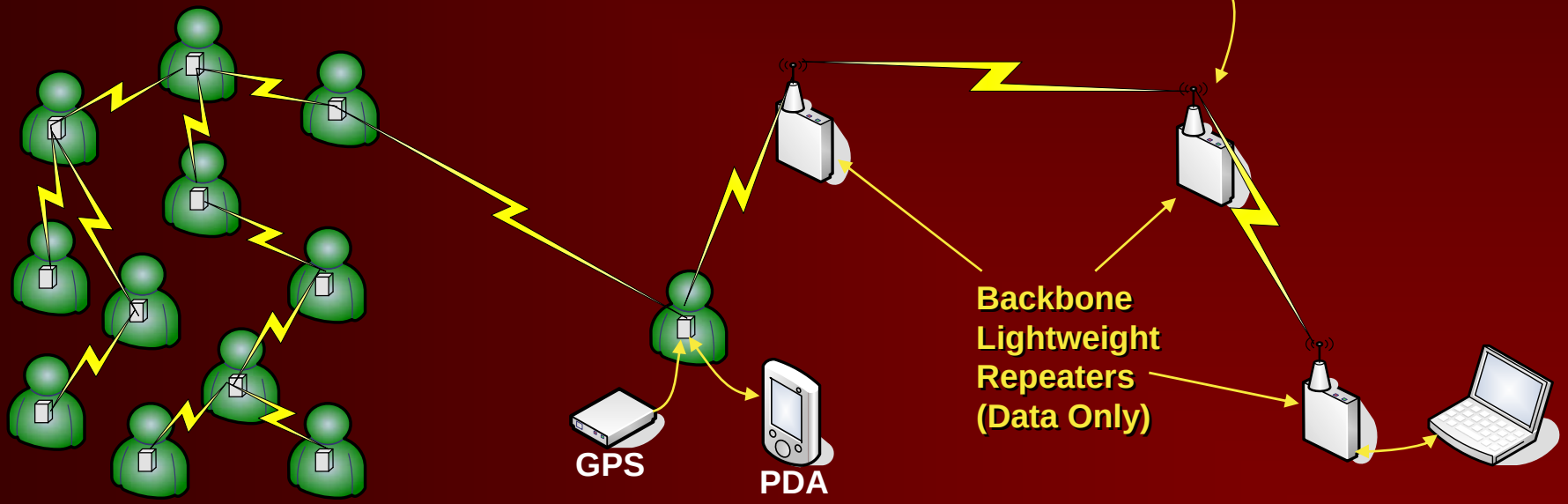
SPARNET Squad Area Network (SAN)

LAND NAV

TRAINING/FTX

- LOST
- SEPARATED
- PANIC
- INJURY
- STATIONARY

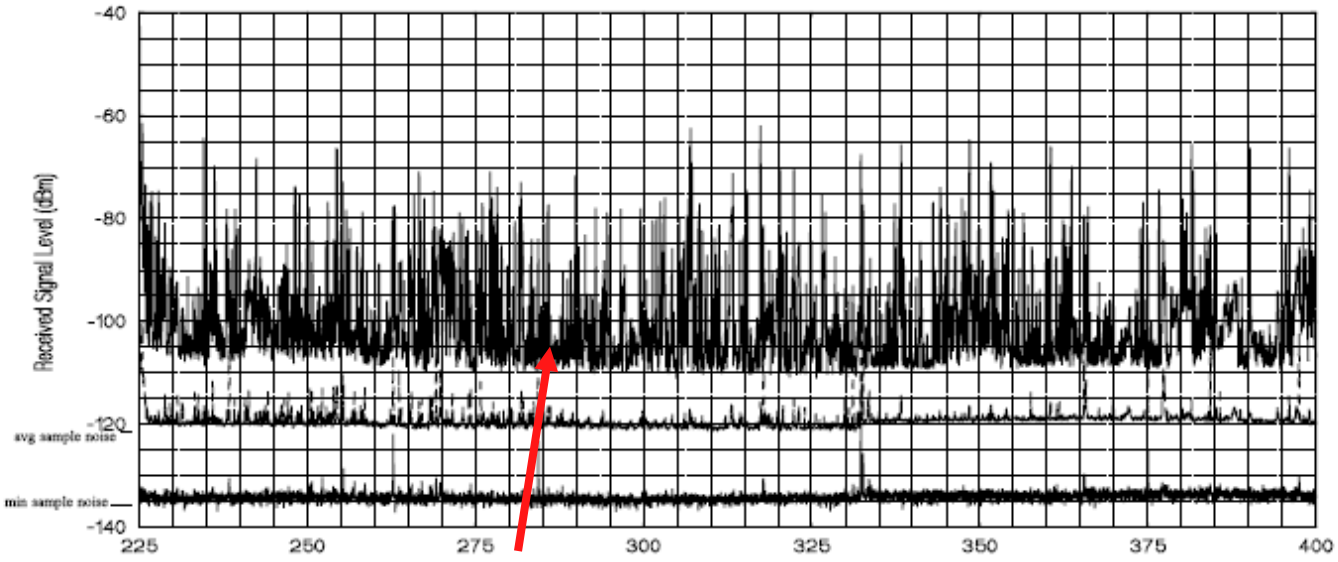
Alert Mechanism



How a “Cognizant Radio” Helps

GOVERNMENT ALLOCATIONS:	FIXED, MOBILE, 1.	2.	FIXED, MOBILE, 3.
NON-GOVERNMENT ALLOCATIONS:		2.	3.
GENERAL UTILIZATION:	Military tactical and training communications including air traffic control (ATC).	2.	

225 328.6-335.4 400.05



Auto-detect and exploit minimum interference locations

1. Government usage is limited to military services; additionally, 235-322 MHz is allocated on a primary basis to the mobile-satellite service. 242.95-243.05 MHz is used for search and rescue operations including position-indicating radiobeacons.
2. AERONAUTICAL RADIONAVIGATION, instrument landing systems (ILS) only.
3. 399.9-400.05 MHz: RADIONAVIGATION-SATELLITE, MOBILE-SATELLITE (Earth-to-space).

Figure 9. NTIA spectrum survey graph summarizing 4,300 sweeps across the 225-400 MHz range (System-1, band event 15, swept/m3 algorithm, sample detector, 30-kHz bandwidth) at Los Angeles, CA, 1995.

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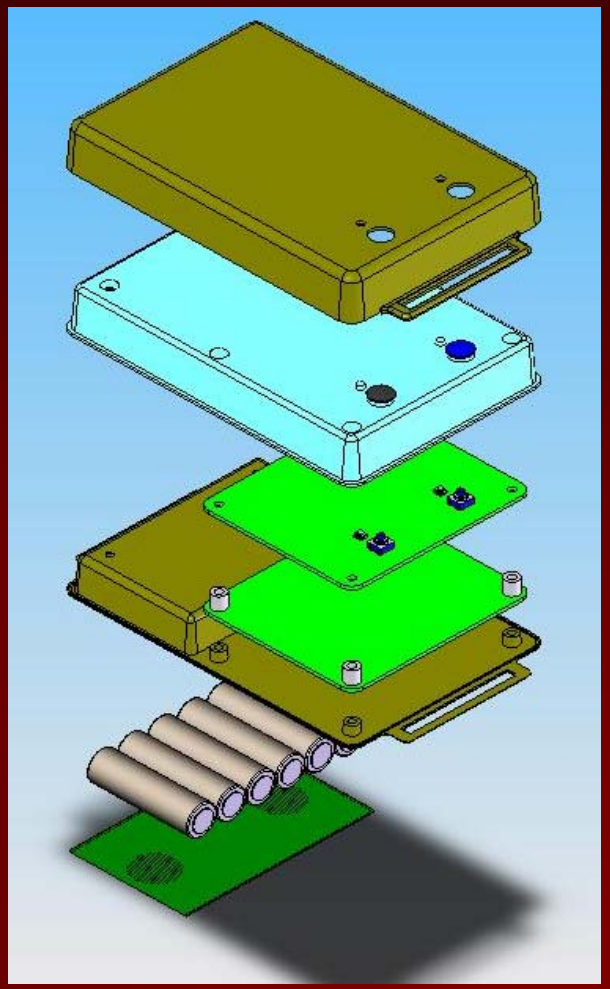
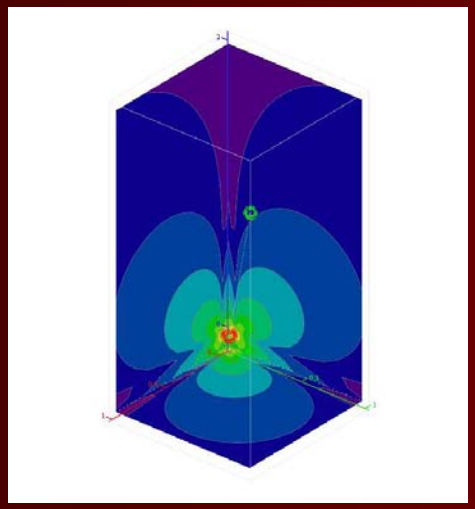
SAN Radio and Antenna

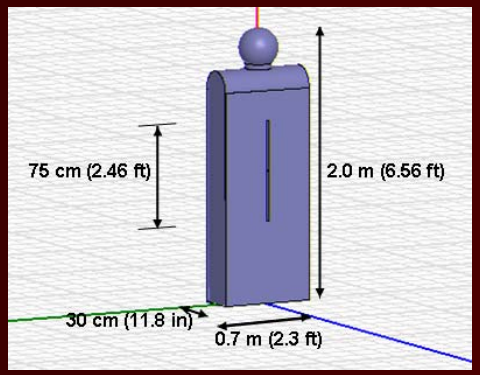
- Software-Defined-Radio (SRD)
- Near-Field-Communication Hub (forms links to sensors)
- Enclosure, seal, circuit card assemblies, lower cover, batteries, battery cover
- Engineering unit LxWxH: 6”x3.7”x1”

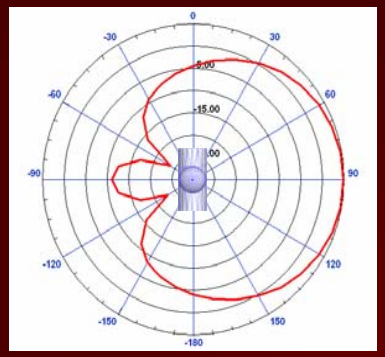




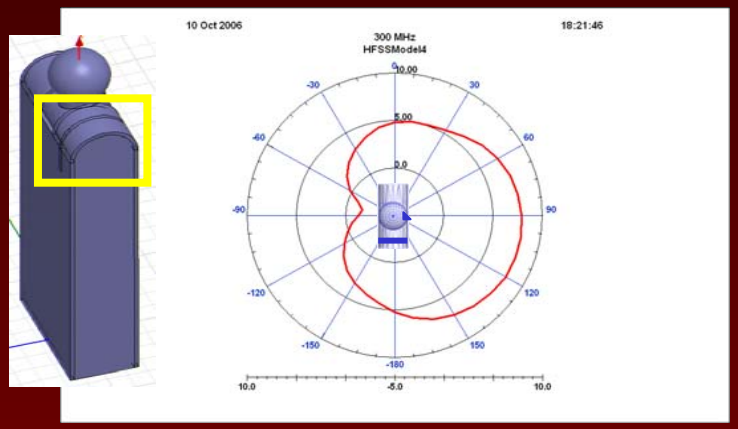
SAN Body-Worn Antenna

Front Position: Double Null



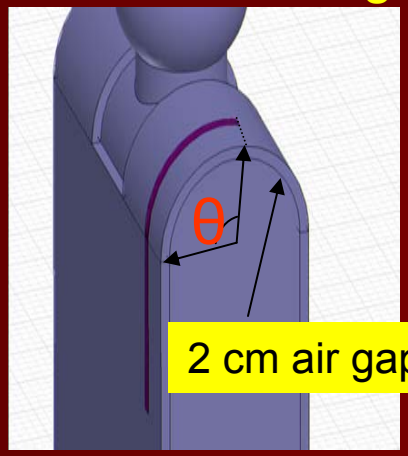


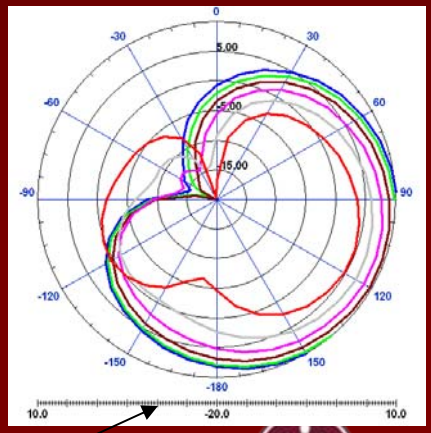
Shoulder Position: Reduced Nulls



Risk-Reduction by Extensive Analysis, Modeling and Simulation

Angle Positioning





Best location: θ = 165°

Squad Area Network (SAN) Elements

Wearable antenna

SAN module

AA Batteries

SPARNET Initial Objectives

- Battery life: >18 hours (TBD)
- Radio Unit (SDR with cognizant-radio capabilities)
  - Flexible modulation options
  - Prototype size: 6” x 3.7” x 1” (~15 cm x 9 cm x 2.5 cm)
  - Weight: ~1kg
  - Inductive network links
  - Target single-hop range: >300 meters
  - Target soldier-911 range: ~1000 meters
  - Prototype operating band: 225 MHz – 380 MHz
  - Frequency de-confliction: user-selected keep-out bands
- Antenna
  - Body-worn, integrated into hydration unit
  - Link to external repeaters for increased performance

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SPARNET IN SUMMARY...

- Risk-managed to address significant unmet needs
- Minimalist, adaptable, transparent, advanced technology
- Scalable and cost-effective
- Improves training effectiveness and safety
  - Situational and medical awareness
  - Casualty avoidance
  - Casualty management
- Enables innovative, cutting-edge physiologic research
- Enables cutting-edge network science research


YPG
YTC

Acknowledgement

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- Drew Barnett
- Stephen Mullen
- Chi-Chih Chen
- Ranger Training Brigade
- TATRC

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